



**Land Use and Travel Demand  
Forecasting Models**

*Recommendations for  
Integrated Land Use and  
Travel Models*

final  
report

*prepared for*

**Puget Sound Regional Council**

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# Table of Contents

1.0	Introduction .....	1-1
1.1	Purpose of the Report .....	1-1
1.2	Report Organization .....	1-2
2.0	Recommendations for Model Design .....	2-1
3.0	Recommendations for Model Implementation .....	3-1
3.1	Short-Range Implementation Recommendations .....	3-1
3.2	Mid-Range Implementation Recommendations .....	3-4
3.3	Long-Range Implementation Recommendations .....	3-5
4.0	Addressing Design Requirements .....	4-1
5.0	Data Requirements .....	5-1
6.0	Costs and Benefits .....	6-1
6.1	Costs .....	6-1
6.2	Benefits to PSRC and Member Agencies .....	6-3



# List of Tables

2.1	Land Use Model Recommendations.....	2-4
2.2	Passenger Travel Demand Model Recommendations .....	2-5
2.3	Freight Forecasting Models.....	2-7
2.4	Assignment and Traffic Operations Models.....	2-8
2.5	Recommendations for Representation .....	2-9
3.1	Expanded Trip Purposes in <i>New</i> Model.....	3-2
4.1	Design Requirements addressed by Recommendations for Integrated Land Use and Travel Models.....	4-1
5.1	Data Requirements for Implementation of Model Recommendations.....	5-2
6.1	Cost Estimates by Phase .....	6-4
6.2	Cost Estimates by Model Type .....	6-5



# List of Figures

2.1	Interacting Markets for Real Estate, Labor and Transportation .....	2-1
2.2	Overview of Model System Design .....	2-3
3.1	Proposed Web-Based User-Interaction with Model System .....	3-5
6.1	Sequencing and Dependency of Model Recommendations.....	6-2



# 1.0 Introduction

This document is one of a series of documents developed for the Documentation, Enhancement, and Support of the Puget Sound Regional Council's Land Use and Travel Demand Forecasting Models. The full series of reports is as follows:

- Executive Summary,
- Documentation of the *Current* Models,
- Validation of the *Current* Models,
- Documentation of the *New* Models,
- User's Guide of the *New* Models,
- Validation of the *New* Models,
- Data Sources for Travel Demand and Land Use Forecasting,
- Assessment of Model Requirements,
- Review of Literature and Operational Models, and
- Model Design Recommendations.

There is one additional report that was prepared for the Washington State Department of Transportation on the *Response of Concerns about the PSRC Travel Models*. This report was developed in conjunction with the validation for the *current* and *new* models and provided responses to concerns that have been raised about the PSRC travel models.

## ■ 1.1 Purpose of the Report

The purpose of the *Recommendations for Integrated Land Use and Travel Models* is to develop recommendations from the assessment of model requirements and review of the literature and operational models for the Puget Sound Regional Council. This is the third of three phases in the design process to develop recommendations that respond effectively and cost-efficiently to the modeling requirements. The three-phase process was to design land use and transportation models for the Puget Sound Regional Council and its members:

1. The first phase was to obtain responses to the requirements analysis and is described in the *Assessment of Model Requirements*,
2. The second phase was to review the literature and operational models and is described herein, and

3. The third phase was to develop recommendations based on the first two design phases and on the *Validation Of The New Models*.

## ■ 1.2 Report Organization

This report contains six sections that together describe the recommendations for developing land use and travel demand forecasting models for the Puget Sound region over the next generation. Section 2.0 describes the overall design of the recommendations and details the recommendations by the four primary functional areas:

1. Land Use Models,
2. Passenger Travel Demand Models,
3. Freight Forecasting Models, and
4. Assignment and Traffic Operation Models.

Section 3.0 describes the recommendations for model implementation in the short range (through the end of 2002), the mid-range (through mid-2005), and the long range (through 2007). Section 4.0 presents how each recommendation addresses the design requirements identified in the *Assessment of Model Requirements*. Section 5.0 describes data requirements for the model design requirements, which are described in more detail in the *Data Sources for Travel Demand and Land Use Forecasting*. Section 6.0 presents the costs to implement the model design recommendations by phase and by model type, as well as the benefits associated with implementing these recommendations.

## 2.0 Recommendations for Model Design

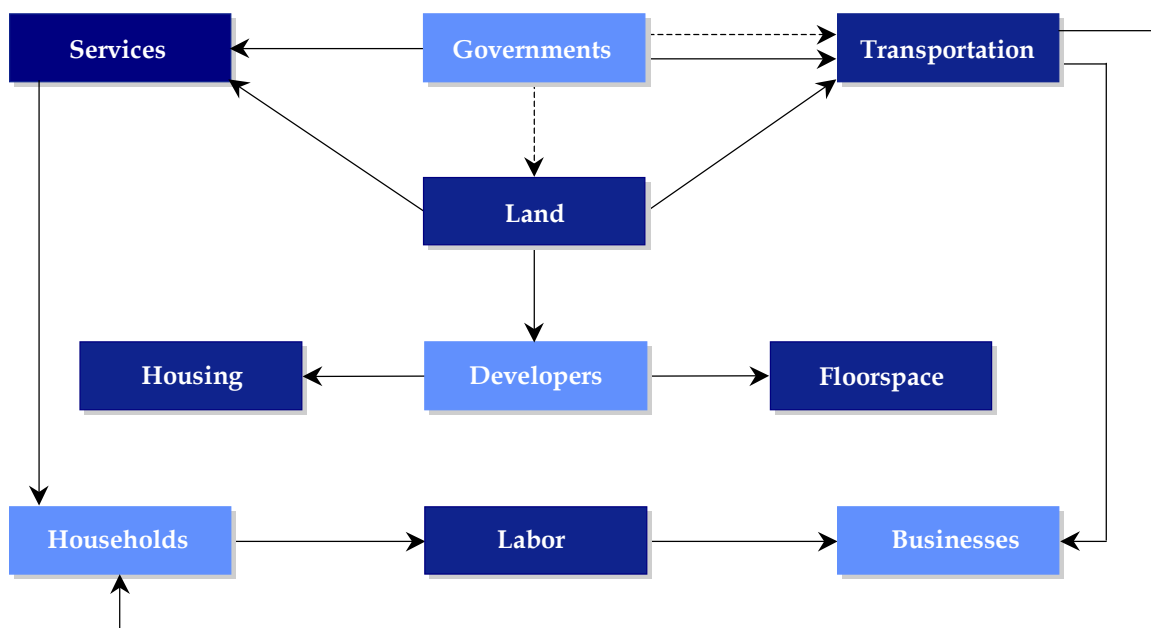
The recommendations for developing new land use and travel demand models for use by the PSRC and its member governments draw on the analysis of policy requirements and on the review of the literature and operational models in the preceding sections, as well as on the results of the model validation and data assessment tasks of this project. The key highlights of these recommendations for the model design are:

- Represent real estate, labor, and transportation demand and supply market interactions, as shown in Figure 2.1, within an integrated model system. COMPLETED
- Represent real estate and labor demand and supply, and their interaction as dynamic processes using annual time periods at the parcel level. COMPLETED
- Represent the temporal dimensions of activity and travel demand using as much detail that is practical for implementation. In the mid-term recommendations, we recommend five or more discrete time periods per day; and in the long-term recommendations, we recommend considering using five to 10-minute intervals (or continuous time) per day. Time of day models for auto have 32 time periods and assignments of these models are for either 5 or 15 time periods, depending on the use of the output. Time of day models for transit have 5 time periods. Feedback on generalized costs are completed for the 5 time periods. Represent activity locations at the parcel level. COMPLETED
- Represent behavior according to agent and timeframe, rather than in traditional model components that artificially separate land use and transportation:
  - **Household Housing Demand, Labor Supply, and Vehicle Demand** – Represent household choices of residence, workplace, and vehicle ownership in an integrated model component of long-term household choices influenced by multimodal (including non-motorized) accessibility to activities; COMPLETED
  - **Person Vehicle Allocation, Activity Generation, and Tour Pattern** – Represent intra-household vehicle allocation, activity generation and scheduling, and stop and tour locations and characteristics within an integrated personal travel demand model component, closely interacting with long-term household choice model; This is, in part, the subject of the current Activity Model Work Plan and Tour Generation Model RFP.
  - **Business Real Estate and Labor Demand, Commodity Transport Demand** – Represent business choices of location, employment level, and commodity transport in closely-integrated model components; COMPLETED The commodity transport is a

hybrid truck forecasting model based on commodity flows and employment locations; this model will be updated in the coming year.

- **Real Estate Supply** - Represent developer choices of new construction and redevelopment of housing and nonresidential space in an integrated model component; COMPLETED
- **Transportation Supply** - Represent multimodal transportation system supply, including non-motorized modes; Current models represent transportation system supply for all motorized modes, but do not represent walk or bike networks yet. Some of these data exist and supplement data sources will be incorporated in the future to represent these non-motorized modes.

**Figure 2.1 Interacting Markets for Real Estate, Labor and Transportation**



—> Flow of consumption from supplier to consumer.

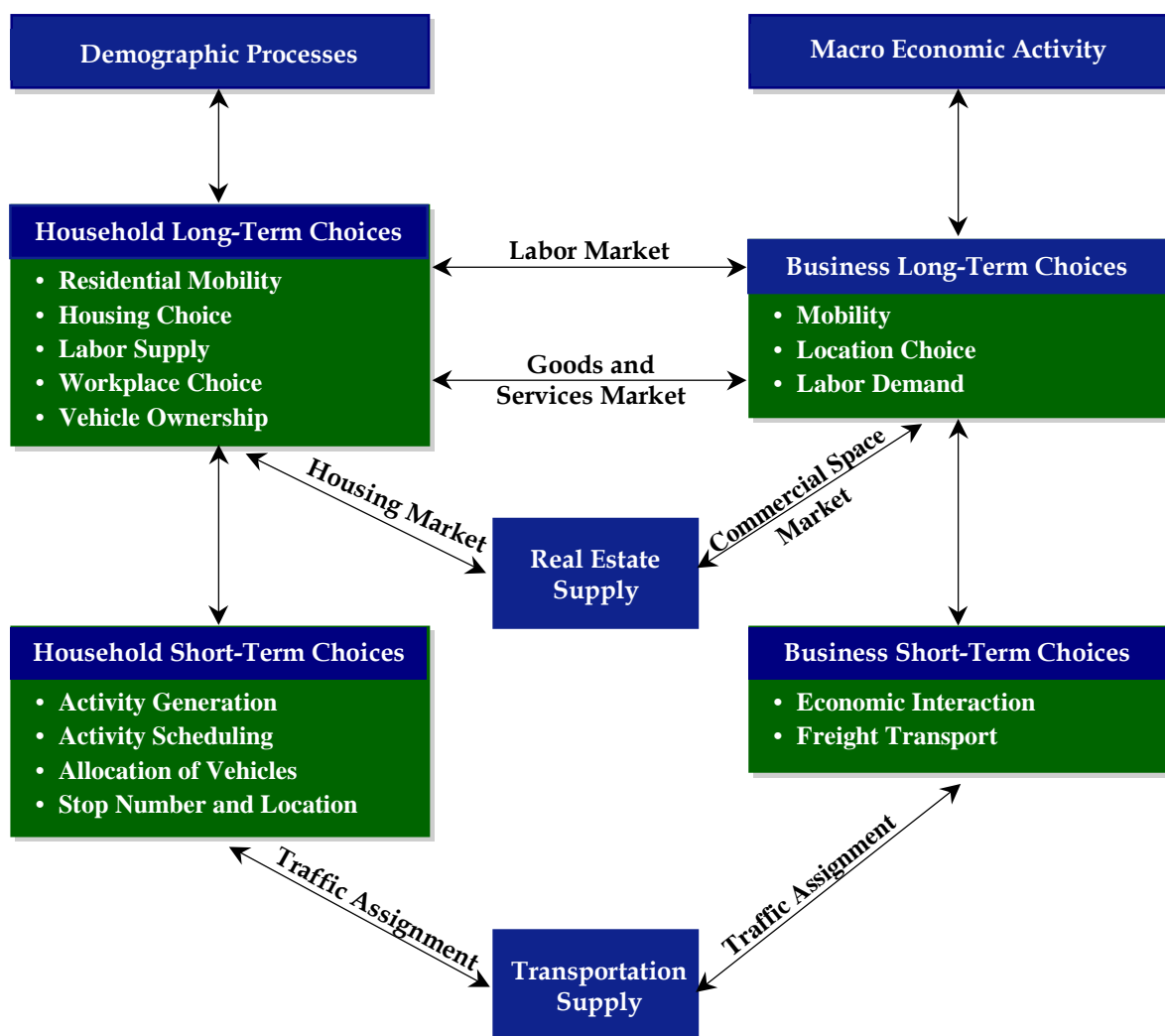
---> Regulation or pricing.

- **Real Estate Market Interactions** - Represent interactions of real estate demand and supply, and the resulting vacancy and price effects; COMPLETED
- **Labor Market Interactions** - Represent interactions of labor supply and demand, and the resulting vacancy and wage effects; and COMPLETED
- **Transportation Market Interactions** - Represent interactions of travel demand and supply, and the resulting patterns of congestion delay and travel volume. Current models represent travel demand and supply, including congestion delay and travel volumes, in all parts of the modeling system except trip generation, which is the subject of the current Activity Model Work Plan and Tour Generation RFP.

The proposed model system design is responsive to virtually all the requirements identified in Phase 1 of this model design process, but prioritizes some of the model extensions into a long-term timeframe through 2007. An overview of the model system design is presented in Figure 2.2.

These recommendations for the design of the new models are further detailed by model component in Tables 2.1 through 2.4, addressing the land use, passenger travel, freight, and assignment components, respectively. Table 2.5 details the recommendations for representation of agents, objects, and behavior for the land use and travel models.

**Figure 2.2 Overview of Model System Design**



**Table 2.1 Land Use Model Recommendations**

<b>Element</b>	<b>Options and Recommendations (in bold)</b>	<b>Reasons for Recommendation</b>
Temporal Framework	Cross-sectional <b>Dynamic*</b>	Accommodates many different time scales relevant to land use; More useful for policy analysis; Consistent with behavioral approach; and Can take advantage of panel survey data.
Temporal Detail	Endpoint forecast 5- to 10-year steps <b>Annual*</b>	Best practice in the U.S.
Spatial Detail	Forecast Analysis Zones (50 to 200) Traffic Analysis Zones Grid Cells (30 to 150 meters) <b>Parcels*</b>	Easy to check for data errors; Good for policy analysis; and Partial data is available for PSRC region.
Theoretical Frameworks	Spatial Interaction Spatial Input Output <b>Behavioral/Decision-Theoretic*</b>	Behavioral realism; Transparency needed for credibility; Good for policy analysis; and Unifying approach for model.
Analytical Methods	Optimization <b>Discrete Choice*</b> Bayesian	Allows modeling of choices.
Agent Detail	Aggregate cross-classification into types Microsimulation list with attributes*	More efficient to maintain list of attributes than many cross-classifications; Ease of maintaining database; Supports equity analysis; Supportive of discrete choice framework because uses disaggregate data; and With many cross-classifications, data unwieldy.
Land Use-Travel Model Integration	Loosely coupled* Integrated	Consistent approach; and Reflect substitutions across short- and long-term choice behavior.
Macro-economic Model Integration	<b>Link to STEP PSEF Model in mid-term*</b> <b>Develop Multi-region Hybrid I/O-Econometric Model in long-term</b>	Support freight modeling; Interact with statewide scale models; and Incorporate bottom-up effects of policies.
User-specified Events	No direct representation <b>Accommodate user-specified events: major development, business, or policy change*</b>	Recognize limitations of models to predict events such as a major corporate relocation; Do sensitivity analysis on effects of an event; Incorporate information available to planners.

\*Denotes current practice at PSRC.

**Table 2.2 Passenger Travel Demand Model Recommendations**

Element	Options and Recommendations (in bold)	Reasons for Recommendation
Time-Unit for Analysis	Weekday* <b>Weekday and Weekend</b> Entire week	Captures different characteristics of weekend and weekdays (i.e., peaking characteristics); and Supports air quality analysis.
Intra-individual variations in activity-travel pattern	<b>Ignored</b> (i.e., the activity-travel pattern is modeled based on data from one weekday or one weekend day or one week, depending on the time unit used in the analysis)* Recognized (requires multiple time-unit observations)	Data limitations; and No operational models that include this.
Temporal Representation	<b>Discrete with further consideration of continuous</b> Peak versus off-peak More disaggregate time periods (for example, four to six time periods in the day) * Continuous-time	Use five or six time periods for better temporal resolution; Supports policy analysis (i.e., congestion pricing); and Practical implementation issues to move towards continuous.
Spatial Detail	Forecast Analysis Zones (50 to 200) Traffic Analysis Zones* Grid Cells (30 to 150 meters) <b>Parcels</b>	Same as land use model reasons.
Behavioral Analysis	Aggregate trip-based approach* Disaggregate trip-based approach with no interactions among trips Disaggregate trip-based approach with indirect recognition of interactions among trips Disaggregate tour-based approach with interactions among stops in a tour, but no interactions among tours Disaggregate tour-based approach with indirect recognition of interactions among tours <b>Activity-based approach with explicit interactions among tours and stops</b>	Supports policy analysis (i.e., congestion pricing); and Recognizes choices of household members.

\*Denotes current practice at PSRC.

**Table 2.2 Passenger Travel Demand Model Recommendations (continued)**

<b>Element</b>	<b>Options and Recommendations (in bold)</b>	<b>Reasons for Recommendation</b>
Modeling Focus	<p>Trip generation*</p> <p>Activity scheduling only; considers activity generation as pre-determined (i.e., assumes that number of stops of each activity type, and one or more attributes of the stops as given and models sequencing and time-scheduling of entire activity-travel pattern)</p> <p><b>Activity generation and scheduling with no explicit integration with traffic</b></p>	<p>The current activity-based models are implemented this way so this is a practical limitation.</p>
Interaction Considerations	<p>Interaction in activity-travel and car allocation decisions among individuals in a household</p> <p>Interaction in space and time</p> <p>Interaction between in-home and out-of-home activities</p>	<p>Shows tradeoffs in choices.</p> <p>(In all these cases, the interactions may be ignored or may be considered at one of several different levels of comprehensiveness.)</p>
Analytical Methods	<p>Cross-classification*</p> <p>Gravity methods*</p> <p>Statistical (based on pattern-recognition or a variant of this technique)</p> <p>Econometric</p> <p>Discrete choice*</p> <p><b>Discrete/continuous model systems</b></p> <p>Hazard duration systems</p> <p>Structural equation systems</p> <p>Rule-based computational-process systems</p> <p>Linear and/or non-linear optimization formulations</p> <p>Combinations of the above</p>	<p>Used widely in practice</p> <p>Allows for validation of model</p> <p>Discrete/continuous models are more flexible; these models are recommended in the long term.</p>
Agent Detail	<p><b>Microsimulation list with attributes</b></p> <p>Aggregate cross-classification into types*</p>	<p>Same as land use model reasons.</p>

\*Denotes current practice at PSRC.

**Table 2.3 Freight Forecasting Models**

<b>Element</b>	<b>Options and Recommendations (in bold)</b>	<b>Reasons for Recommendation</b>
Time Unit for Analysis	<b>Weekday*</b> Weekday and Weekend Entire week	Data currently available.
Temporal Representation	<b>Discrete-time</b> Peak versus off-peak More disaggregate time periods (for example, four to six time periods in the day) * Continuous-time	Shows trucker response to congestion; and Recognizes different temporal patterns of trucks and autos
Spatial Detail	Forecast Analysis Zones (50 to 200) Traffic Analysis Zones* Grid Cells (30 to 150 meters) <b>Parcels</b>	Same as land use models.
Representation of Objects	Trucks* <b>Commodities by Weight and Value</b> Parcels/Boxes/Shipments	Standard practice; and Allows for translation to mode and time.
Agent Detail	<b>Aggregate cross-classification into types*</b> Microsimulation list with attributes	Data available.
Model Approach	Commodity Flow Vehicle Models <b>Hybrid Approach*</b>	Use Commodity Flow approach for regional/national and international movements; and Use Vehicle Model approach for local or internal truck trips.
Commodity Flow Model Elements	Small-area projections of employment and/or commodity 'flow ends'* Mode choice models reflecting shippers and carriers' decisions Flow models for various types of pickup and delivery, collection and distribution operations	
Vehicle Model Elements	Trip generation relationships based on other variables besides employment: locational variables, such as prevailing land use and employment density Additional trip distribution and traffic assignment variables besides travel time: times weighted lower on truck routes and numbered highways, distance, grades, land use matches at origin and destination	

\*There are currently no freight forecasting models at PSRC, so current practice is not noted on this table.

**Table 2.4 Assignment and Traffic Operations Models**

<b>Element</b>	<b>Options and Recommendations (in bold)</b>	<b>Reasons for Recommendation</b>
Temporal Representation	<b>Discrete-time for regional analysis</b> More disaggregate time periods (for example, four to six time periods in the day) * Continuous time or five 15-minute time slices for subareas Peak versus off-peak	Consistent with other model elements.
Spatial Detail	Traffic analysis zones with centroid connector strategies and/or multi-node loading* <b>Point- or link-based</b>	Supports micro-simulation for subareas
Pedestrian and Bicycle Networks	None* <b>Separate networks</b> Representation of delay	Supports policy analysis
<b>Remaining Elements are provided with multiple options that are all recommendations.</b>		
Estimation of Speed and Travel Time	Functional forms to match HCM relationships Additional link variables - parking, intersection spacing, lane widths, grades, railroad crossings, etc. Separate intersection and link delay functions Weaving sections Measure variability to represent reliability	
Auto Passenger Assignments	Multi-class assignments (SOV and HOV 2, HOV 3+)* Dynamic assignment/queuing: Simplified strategies to model multi-link back-ups due to bottlenecks, time-slice trip tables	
Transit Assignments	Multi-path* Capacity restrained (in vehicle or at park-and-ride lots)	
Truck Assignments	Use of passenger car equivalents* Multi-class assignments by truck type* Use of truck networks, prohibitions, and preferred routes	
Microsimulation Model Elements	The simulation unit: individual drivers versus 'packets' versus flow rates Transfer of O/D and network information from assignment models Driver behavior: gap acceptance, acceleration, deceleration; individual versus typical Random (stochastic) versus average characteristics	

\*Denotes current practice at PSRC; those without notations are not part of current practice.

**Table 2.5 Recommendations for Representation**

Representation	Recommendations
Agents	Households*/persons Businesses/jobs* Developers
Objects	Land* Housing Nonresidential buildings Households*/persons* Businesses/jobs* Political institutions/boundaries Environmental features Infrastructure (roads,* water, sewer, transit service*) Policies
Land Use and Demographic Behavior	Household Choices <ul style="list-style-type: none"> <li>• Formation/dissolution/evolution, residential move</li> <li>• Location choice*</li> </ul> Business choices <ul style="list-style-type: none"> <li>• Creation/dissolution/expansion/ contraction, business move</li> <li>• Location choice (of jobs)*</li> </ul> Real estate development choices <ul style="list-style-type: none"> <li>• Developer land development, developer property development, and developer redevelopment</li> </ul> Person labor market choices <ul style="list-style-type: none"> <li>• Labor market (active, inactive)</li> <li>• If employed, job change, place of work, hours of work/week, work arrangement (flexible versus fixed work schedule, telecommuting or not, compressed work week or regular work week)</li> <li>• Household vehicle ownership*</li> <li>• Real estate prices (prices and rents) and vacancies</li> <li>• Labor market prices (wages) and vacancies</li> </ul>
Travel Behavior	Allocation of activities and care among individuals in a household Generation and scheduling of activities <ul style="list-style-type: none"> <li>• Number of stops of each type, number of tours</li> <li>• Number of stops during work commute</li> <li>• Number of stops by type and sequence in each tour</li> <li>• Mode choice of each tour</li> <li>• Stop attributes (time-of-day of participation, activity duration, and location), and mode</li> </ul>

\*Denotes current practice at PSRC; those without notations are not part of current practice.



## 3.0 Recommendations for Model Implementation

Given the model design recommendations highlighted in the preceding section, the following recommendations address the questions of implementing the proposed model design. Here, we differentiate more clearly between short-, mid-, and long-range recommendations, and deal with more specific aspects of financial and time constraints and opportunities for leveraging resources through cooperative development efforts.

### ■ 3.1 Short-Range Implementation Recommendations

The short-term implementation recommendations are based on the overall recommendation to use the *new* trip distribution and mode choice models with improvements. This would effectively include the following improvements that are already included as part of the new models:

- Expands models to include non-motorized travel in trip generation, distribution, and mode choice models. COMPLETED
- Expands trip purposes in trip distribution and mode choice models as shown in Table 3.1. COMPLETED
- Model coefficients in the *new* trip distribution models are based on more recent travel survey data (from 1985 through 1988) than the model coefficients in the *current* models (from 1971) and model coefficients in the *new* mode choice models are based on local travel survey data (from 1985 through 1988), rather than model coefficients in the *current* models (which were transferred from another city). Model coefficients in the trip distribution models were calibrated using the 1999 household travel survey data; model coefficients in the mode choice models are based on national sources and alternative-specific constants were calibrated using the 1999 household travel survey data.
- *New* home-based work distribution models are segmented by household income (four groups) and vehicle availability (four groups), and estimated using destination choice methods rather than gravity model methods used in the *current* model. This adds explanatory power and accuracy to the *new* models. Destination choice models were changed to gravity model methods because of theoretical problems in the balancing portion of these models.

- *New* mode choice models have more modes in each purpose than the *current* models. Walk and bike modes are added to each purpose; home-based work has transit separated into walk and drive access to transit. COMPLETED

**Table 3.1 Expanded Trip Purposes in *New* Model**

<b>Trip Purpose</b>	<b>Current Trip Distribution</b>	<b>New Trip Distribution</b>	<b>Current Mode Choice</b>	<b>New Mode Choice</b>
Home-based Work	HBW	HBW	Combined HBW	HBW
Home-based College	HBC	HBC	Combined HBW	HBC
Home-based Shop	Combined HBO	HBSH	Combined HBO	Combined HBO
Home-based School	HBSC	HBSC	Combined HBO	HBSC
Home-based Other	Combined HBO	HBO	Combined HBO	Combined HBO
Non-home-based Work	Combined NHB	NHBW	Combined NHB	Combined NHB
Non-home-based Other	Combined NHB	NHBO	Combined NHB	Combined NHB
Commercial Vehicles	CV	CV	None	None
<b>Total Purposes</b>	<b>6</b>	<b>8</b>	<b>3</b>	<b>5</b>

Additional model improvements, described below, would be implemented in the short term (through end of 2002). All of these short-range recommendations would support improvements in the development of integrated land use and activity-based models in the mid-range, except the initial recommendation to calibrate the *new* models for use in the short range. This short-range recommendation to calibrate the *new* models in the short range is intended to provide models that can be used in the interim (from 2002 through 2005).

- Calibrate the *new* trip generation, distribution and mode choice models:
  - Update trip distribution models to correct the destination choice model for home-based work trips to remove balancing procedures and to balance non-work purposes separately. Re-calibrate models to match average trip lengths and district trip tables. Models for all trip purposes were recalibrated, but home-based work trips were changed to a gravity formulation rather than revising the models balancing procedures.
  - Calibrate trip generation model trip rates to better match observed trip rates. Review and update special generator assumptions. Consider adding special generators for airports, recreation, shopping and other major accommodations. COMPLETED

- Calibrate mode choice models to better match observed modal shares, auto occupancy rates and transit trips. This will include adding a post-mode choice program to forecast vanpools and separate them from the bus and auto modes. COMPLETED
- Analyze temporal data from Panel Survey to determine any bias in coefficients over time. COMPLETED
- Review and update input data assumptions:
  - Review and update transit walk access assumptions to correct individual transit trips that have unreasonably high access times. COMPLETED
  - Review and validate highway and transit network assumptions for capacity, speed, time, and distance. This should include revising the free-flow speeds to be fixed inputs, rather than estimated from a daily assignment. COMPLETED
  - Update all cost-related data to represent 2000 dollars. COMPLETED
- Expand the time-of-day model to five time periods (early a.m., a.m. peak, mid-day, p.m. peak, and evening). COMPLETED
- Update external trip tables. This will involve conducting origin-destination surveys at select cordon locations to determine the movements of trips passing through external stations. These surveys may be limited to the largest volume external stations or may include all stations. COMPLETED
- Update trip assignment parameters and assumptions:
  - Refine the volume-delay functions by time period in the trip assignment model to reflect current research in volume-delay behavior for different facility types. This should consider stratifying volume-delay functions by facility type, number of lanes, or speeds. Arterial volume-delay functions should consider intersection delay or signals per mile. Volume-delay functions by time period were updated to reflect current research by facility type, but were not further stratified by number of lanes or speeds. Arterial volume-delay functions do not consider intersection delay or signals per mile. Both the stratification and intersection delay features are under development now.
  - Assignment should be modified to include generalized cost, instead of travel time, to account for costs for auto and transit. This will include tolls, auto operating, and parking costs for auto modes and fares and fees at park-and-ride lots for transit. COMPLETED
  - Refine travel assumptions affecting cross-sound travel, including the ferry mode assumptions for vehicles and the Tacoma Narrows bridge time and capacity assumptions. Some work on this has been done over the last few years, but additional work is ongoing.
  - Review and validate HOV assignment methodology to reflect more accurate estimates of speed and volumes on HOV lanes. Some work on this has been done over the last few years, but additional work is ongoing.
  - Transit assignments should be revised to account for capacity constraint on transit vehicles and at park-and-ride lots. COMPLETED

- Multi-class assignment should be expanded to include trucks by type and buses. This work was completed for trucks, but not buses.
- Incorporate the freight model developed as part of the FAST Phase II study to model the traffic impacts of light-, medium-, and heavy-duty trucks. COMPLETED

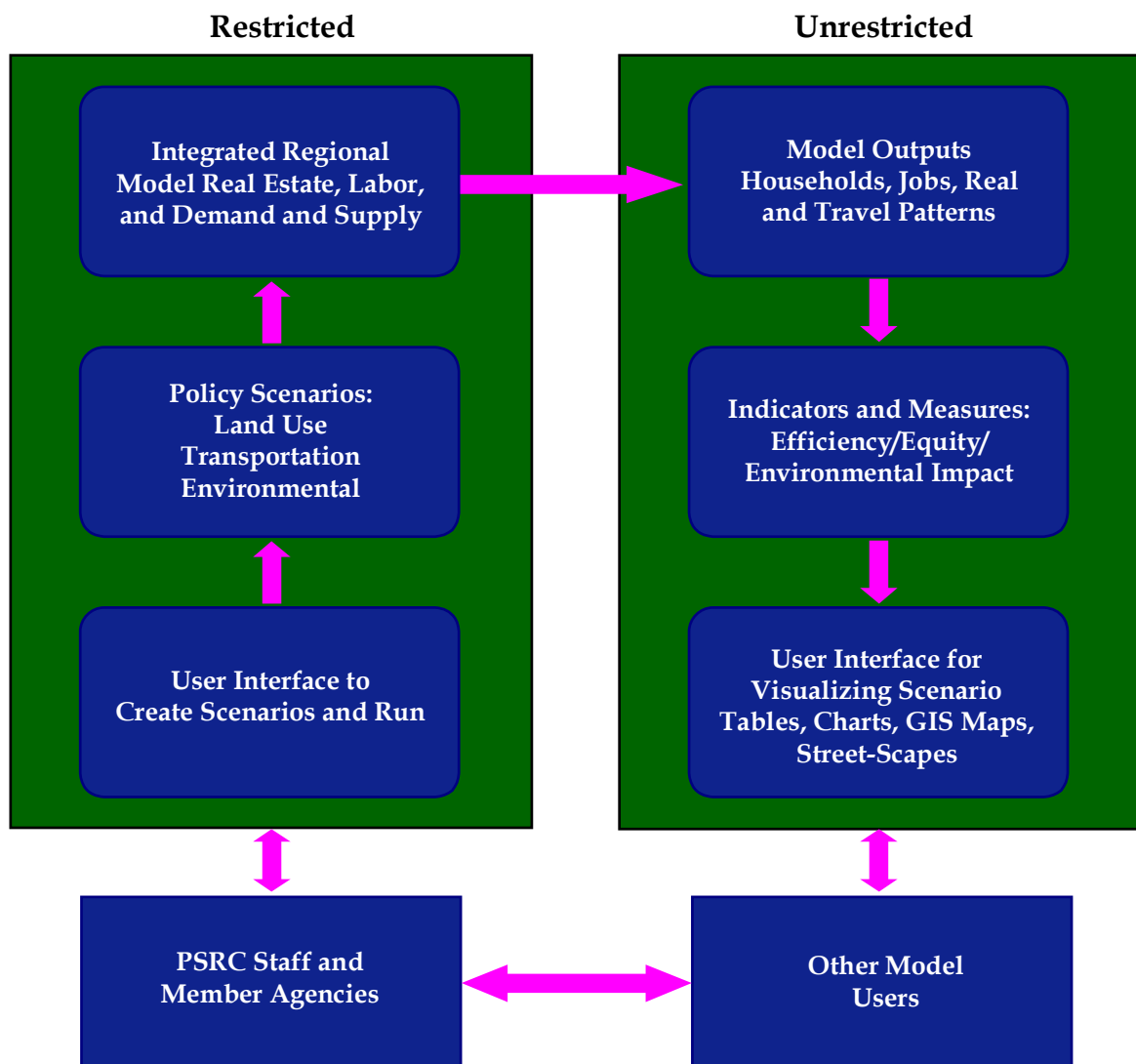
## ■ 3.2 Mid-Range Implementation Recommendations

In the mid-term (through mid-2005):

- Replace the current land use and travel demand forecasting models with an integrated land use and activity-based model:
  - Replace DRAM/EMPAL land use models with a new model that reflects the characteristics proposed in Table 1.1. This work is underway and will be completed in 2008.
  - Integrate long-term household choices of residential location, workplace, and vehicle ownership to reflect their interdependence. COMPLETED
  - Interact with short-term choices of daily activity and travel through multimodal access measures. COMPLETED
  - Replace the trip generation, distribution, mode choice, and time-of-day components of the current travel demand models with an activity-based travel model system with the characteristics proposed in Table 1.2. This model will be adapted from the Portland and San Francisco activity-based models using a discrete-time approach with five periods per day. The models, however, may not retain the same structure as the Portland and San Francisco models. This is because the discrete-time model structure will be developed in a way that most easily lends itself to extension to a continuous-time framework. This is the subject of the current RFP as Phase I; this will be followed by another RFP to complete the process.
- Add a visitor trip model to the resident travel model component. This will involve conducting a travel survey of visitor behavior. This work is planned for 2008-2009.
- Integrate regional economic, land use, activity-based travel model components within an integrated software application with the following extensions: This work will be completed following the completion of the models. The data integration and indicators have been constructed as part of the land use forecasting model development.
  - Add data integration component that assists in diagnosing data quality and consistency, and in the integration and refinement of data inputs for modeling;
  - Add evaluation component that includes flexible construction of indicators and graphical visualization of results in charts and maps; and
  - Add a web-based user interface to allow distributed use of model system, as shown in Figure 2.1.

- Develop institutional partnerships to fund the new regional model development, implementation, and maintenance: This is ongoing.
  - University of Washington: PRISM project and NSF grants.
  - King County, Department of Natural Resources.
  - Other counties and cities in the region.
  - State agencies, such as the Community Trade and Economic Development, the Washington State Department of Transportation, and the Department of Ecology.

**Figure 3.1 Proposed Web-Based User-Interaction with Model System**



### ■ 3.3 Long-Range Implementation Recommendations

In the long term (through 2007):

- Replace the traffic assignment component of the travel models with a dynamic micro-simulation traffic assignment model using five- to 10-minute time intervals. This work is planned for 2008-2009 timeframe.
- Adapt the activity-based travel model to a continuous time (duration) approach to simulate travel demand using five- to 10-minute time intervals consistent with dynamic micro-simulation traffic assignment.
- Expand the activity-based model to simulate travel demand for weekends. This would involve conducting an additional household travel survey on weekend days of 2,000 to 3,000 households.
- Adapt the regional economic model to a multi-region model structure to support commodity-freight transport and better reflect economic linkages to other urban areas within and near Washington. Under consideration.
- Expand and update the commodity-transport model component linked to the multi-region economic model. Under consideration.
- Develop an extended scenario evaluation component, incorporating least-cost planning, risk and uncertainty analysis, and valuation of social and environmental externalities. Some of this work is underway by integrating least-cost planning tools with the travel demand model.

# 4.0 Addressing Design Requirements

The short-, mid-, and long-term recommendations outlined in Section 3.0 of this report address the design requirements established by the survey of user needs. These design requirements and the survey establishing priorities for these requirements are documented in the *Assessment of Model Requirements*. Table 4.1 correlates the design requirements that are met by each of the recommendations. This table demonstrates that all design requirements are met in the long term, and that some design requirements are met incrementally by individual improvements in the short and mid-term.

**Table 4.1 Design Requirements addressed by Recommendations for Integrated Land Use and Travel Models**

Recommendations	Design Requirements Addressed by this Recommendation
<i>Short-Range Implementation Recommendations (Through End of 2002)</i>	
1. Calibrate trip generation, distribution, and mode choice models	Improves evaluation of all modes (8) Analyze effects of land use on transportation (9) Support analysis of TOD (19)
2. Review and update input data assumptions	Improves multimodal assignments (23) Improves evaluation of CMS/TSM (24)
3. Expand the time-of-day model	Analyze effects of transportation pricing policies (1) Supports activity-based framework (7) Analyze commodity and freight transport (21) Improves multimodal assignments (23) Improves evaluation of CMS/TSM (24)
4. Update external trip tables	Improves multimodal assignments (22)
5. Update the parameters in the trip assignment model	Improves evaluation of all modes (8) Improves multimodal assignments (22) Improves evaluation of CMS/TSM (24)
6. Incorporate the freight model	Analyze commodity and freight transport (21) Improves multimodal assignments (22) Analyze effects of environmental factors (11)

**Table 4.1 Design Requirements addressed by Recommendations for Integrated Land Use and Travel Models (continued)**

<b>Recommendations</b>	<b>Design Requirements Addressed by this Recommendation</b>
<i>Mid-Range Implementation Recommendations (Through Mid-2005)</i>	
1. Replace the current land use and travel demand forecasting models with an integrated land use and activity-based model	Analyze effects of transportation pricing policies (1) Analyze effects of growth management policies (2) Analyze effects of land use policies (3) Analyze short- and long-term policy effects (4) Analyze travel using activity-based framework (7) Analyze all modes of travel (8) Analyze induced demand (10) Analyze effects of environmental factors (11) Analyze the effects of TDM strategies (12) Analyze the effects of transportation on land use (13) Analyze effects of urban design (14) Analyze household choices (15) Analyze demographic processes (17) Analyze real estate development (18)
2. Add a visitor trip model	Analyze all modes of travel (8) Improves multimodal assignments (23)
3. Integrate regional economic, land use, activity-based travel model components within integrated software architecture, with data integration, flexible construction of indicators, and graphical visualization of results in charts and maps.	Analyze the effects of land use on transportation (9) Analyze the effects of transportation on land use (13) Provides for improved assessment of scenarios (6) Manage data needs (27) Achieve reasonable performance (28) Analyze household choice interaction (16) Support analysis of Transit-Oriented Design (19) Allow multimodal cost-benefit analysis (30) Promote common use of data (26) Support participatory policy process (5) Support visualization techniques (29)
4. Develop institutional partnerships to fund the model development, implementation, and maintenance	Support participatory policy process (5) Promote common use of data (26) Manage data needs (27) Improve project cost-effectiveness and feasibility

**Table 4.1 Design Requirements addressed by Recommendations for Integrated Land Use and Travel Models (continued)**

<b>Recommendations</b>	<b>Design Requirements Addressed by this Recommendation</b>
<i>Long-Run Implementation Recommendations (Through Mid-2007)</i>	
1. Replace the traffic assignment component of the travel models with a dynamic microsimulation traffic assignment model	Analyze multimodal assignments (23) Analyze traffic operations (24) Analyze Intelligent Traffic Systems (25)
2. Adapt the activity-based travel model to a continuous time (duration) approach	Analyze effects of transportation pricing policies (1) Analyze effects of environmental factors (11) Analyze traffic operations (24) Allow multimodal cost-benefit analysis (30)
3. Expand this model from average weekday to weekday and weekend	Analyze effects of environmental factors (11) Analyze traffic operations (24) Allow multimodal cost-benefit analysis (30)
4. Adapt the regional economic model to a multi-region model structure	Analyze economic activity (20) Analyze commodity and freight transport (21)
5. Expand and update the commodity-transport model component linked to the multi-region economic model	Analyze commodity and freight transport (21) Analyze modal diversion of goods movement (22)
6. Develop an extended scenario evaluation component, incorporating least-cost planning, risk and uncertainty analysis, and valuation of social and environmental externalities	Support participatory policy process (5) Support scenario assessment (6) Support visualization techniques (29) Allow multimodal cost-benefit analysis (30) Perform uncertainty analysis (31)



## 5.0 Data Requirements

The principal data requirements for the model design recommendations are outlined in Table 5.1. The recommendations for model improvements that are not listed in Table 5.1 have no data requirements.

The data that would be used in estimating and applying the proposed model design are highly disaggregate, but generally available from existing data maintenance efforts. A significant portion of any large scale modeling effort is the effort expended to integrate input data and ensure that it is of sufficient quality for use in the modeling application. In the proposed model design, the data requirements described below will need to be drawn from various sources (such as county tax assessment departments), which have differing standards and classification systems. Due to the use of these data for operational purposes, extensive experience of the consultants with the use of such data in modeling applications elsewhere and working experience with much of the local data that is proposed for use, we suggest that the data are suitable for the purposes intended. There will need to be an investment in software tools to assist in the data cleaning and integration process to diagnose problems in the data and assist the user in resolving inconsistencies. These costs are incorporated into the estimates presented in Section 5.0. The cost estimates will need to be refined when the model design recommendations are expanded to include more detail on the model specifications. We also recommend consideration in the long term of efforts to develop partnerships with member governments to incorporate corrections to the source data, or collaborate in the data cleaning and integration process.

The proposal to use parcel-level data in the development and application of the integrated land use and transportation model design proposed in the mid-term recommendations warrants further elaboration here. The main reasons for the recommendation to use parcel-level data in the model design are as follows:

- Parcels are the elemental unit of land ownership, land use, and location.
- Parcel records are available for each of the four counties in the region, in GIS form, and with the relevant attributes of land area, land use, zoning, land value, improvement value, housing units, nonresidential square feet, and year built (if applicable). These records are being maintained for public purposes and are available and appropriate for use in land use and transportation planning.
- Land use policies developed by local jurisdictions (cities and counties) are generally applied at a parcel level, so aggregating parcels make interpretation of these policies more difficult.

**Table 5.1 Data Requirements for Implementation of Model Recommendations**

Recommendations	Data Requirements
<i>Short-Range Implementation Recommendations (Through End Of 2002)</i>	
1. Calibrate trip generation, distribution and mode choice models	Observed data compiled for the <i>Documentation and Validation of the New Models</i> Temporal data analysis from the Panel Survey Updated data on special generators Socioeconomic and demographic indicators of zones Observed data on bicycle and pedestrian volumes in selected areas
2. Review and update input data assumptions	Observed data compiled for the <i>Documentation and Validation of the New Models</i>
3. Expand the time-of-day model	1999 Household Activity Survey Network level-of-service skims for five time periods Observed data on volumes by mode (highway and transit) for five time periods
4. Update external trip tables	Collect origin destination surveys at select external stations (a minimum of four and maximum of 18 external stations)
5. Update the parameters in the trip assignment model	Observed data on volumes by sub-mode (SOV and HOV) for five time periods
6. Incorporate the freight model	Observed data on volumes by vehicle type (auto and light, medium, and heavy trucks) for five time periods
<i>Mid-Range Implementation Recommendations (Through Mid-2005)</i>	
1. Replace the current land use and travel demand forecasting models with an integrated land use and activity-based model	<p data-bbox="777 1035 857 1062"><u>Needed:</u></p> <p data-bbox="777 1066 1424 1178">Parcel files from King, Kitsap, Pierce, and Snohomish (fields required are land value, improvement value, land area, land use, number of housing units, building area, year built, and zoning)</p> <p data-bbox="777 1182 1317 1209">Building permits (PSRC collects from jurisdictions)</p> <p data-bbox="777 1213 1435 1266">Establishment data, government and educational survey from ESD</p> <p data-bbox="777 1270 1118 1297">Census 2000: PUMS, SF3, CTPP</p> <p data-bbox="777 1302 1122 1329">1999 Household Activity Survey</p> <p data-bbox="777 1333 1146 1360">Puget Sound Transportation Panel</p> <p data-bbox="777 1365 1341 1392">Observed data on volumes and travel times by mode</p> <p data-bbox="777 1396 878 1423"><u>Desirable:</u></p> <p data-bbox="777 1428 1382 1493">Infrastructure (roads, water, sewer) development history from WSDOT, utilities</p> <p data-bbox="777 1497 1143 1524">Subdivision records from counties</p> <p data-bbox="777 1528 1289 1556">Linked establishment records over several years</p> <p data-bbox="777 1560 1281 1587">Stated-preference survey for household choices</p> <p data-bbox="777 1591 1393 1656">Real estate and labor market conditions over several years (vacancy rates, rents, prices, unemployment rates, wages)</p> <p data-bbox="777 1661 1354 1713">Stated-preference survey for attitudes on parking, ITS, and/or transit ridership</p> <p data-bbox="777 1717 1435 1745">Urban form variables, such as pedestrian environment factors</p> <p data-bbox="777 1749 1328 1814">Time-use surveys of in-home and out-of-home activities</p> <p data-bbox="777 1818 857 1845"><u>Needed:</u></p> <p data-bbox="777 1850 1435 1911">Conduct Visitor Trip Survey of 500 to 1,000 visitors on origin-destination, purpose, and mode characteristics of travel</p>
2. Add a visitor trip model	

**Table 5.1 Data Requirements for Implementation of Model Recommendations (continued)**

Recommendations	Data Requirements
<i>Long-Run Implementation Recommendations (Through Mid-2007)</i>	
1. Replace the traffic assignment component of the travel models with a dynamic microsimulation traffic assignment model	Observed data on volumes by mode (highway and transit) for smaller time increments (hourly or 15-minute increments)
2. Adapt the activity-based travel model to a continuous time (duration) approach	Observed data on volumes by mode (highway and transit) for smaller time increments (hourly or 15-minute increments)
3. Expand this model from average weekday to weekday and weekend	New household travel survey on weekend days of 2,000 to 3,000 households Observed data on volumes by mode (highway and transit) for weekend days
4. Adapt the regional economic model to a multi-region model structure	Economic series from Bureau of Labor Statistics, Bureau of Economic Analysis, Commercial Vendors
5. Expand and update the commodity-transport model component linked to the multi-region economic model	Origin-destination data for commodity flows Imports and exports of commodity flows at ports and borders

- Use of parcel level data would make coordination with local jurisdictions more straightforward than current practice, and would reduce inconsistency. Local jurisdictions would be able to define their own land use policies and assumptions and communicate these to the PSRC for use in modeling.
- The use of a common level of detail and data would make it easier for member governments to adapt and use the model for their own planning activities.
- Cross-referencing of data sources such as business establishment data and land use is made more difficult if data are aggregated into other geographic units.
- Analysis of errors and inconsistencies in data is most straightforward to do at the original level of the data. Aggregation into zones or other geographies makes the identification of problems and inconsistencies within and between land use and employment data difficult.
- A high level of detail supports development of a model design that is sensitive to issues, such as:
  - Urban design;
  - Pedestrian characteristics; and
  - Access to transit.

The use of parcel data would involve addressing questions of inconsistency in coding and data standards across the four counties. It also involves assessing the degree of accuracy required for the intended application of modeling land use and transportation. First, while differences in naming conventions can be easily resolved, differences in policies that

have different interpretations (for example zoning), need not be forced to a single standard. There is no reason that local policies could not be used as locally defined for the purposes of modeling. Second, the level of accuracy that would be needed for modeling purposes is on the order of 10 percent at the regional level, and many of the large and systematic errors in the parcel data can be identified and often corrected or adjusted using automated diagnostic techniques. There are ongoing projects developing such tools now that would be available for this project.

## 6.0 Costs and Benefits

The model recommendations represent a “wish-list” of all model improvements needed to address all design requirements. These recommendations can be further divided into four categories as presented in Figure 6.1.

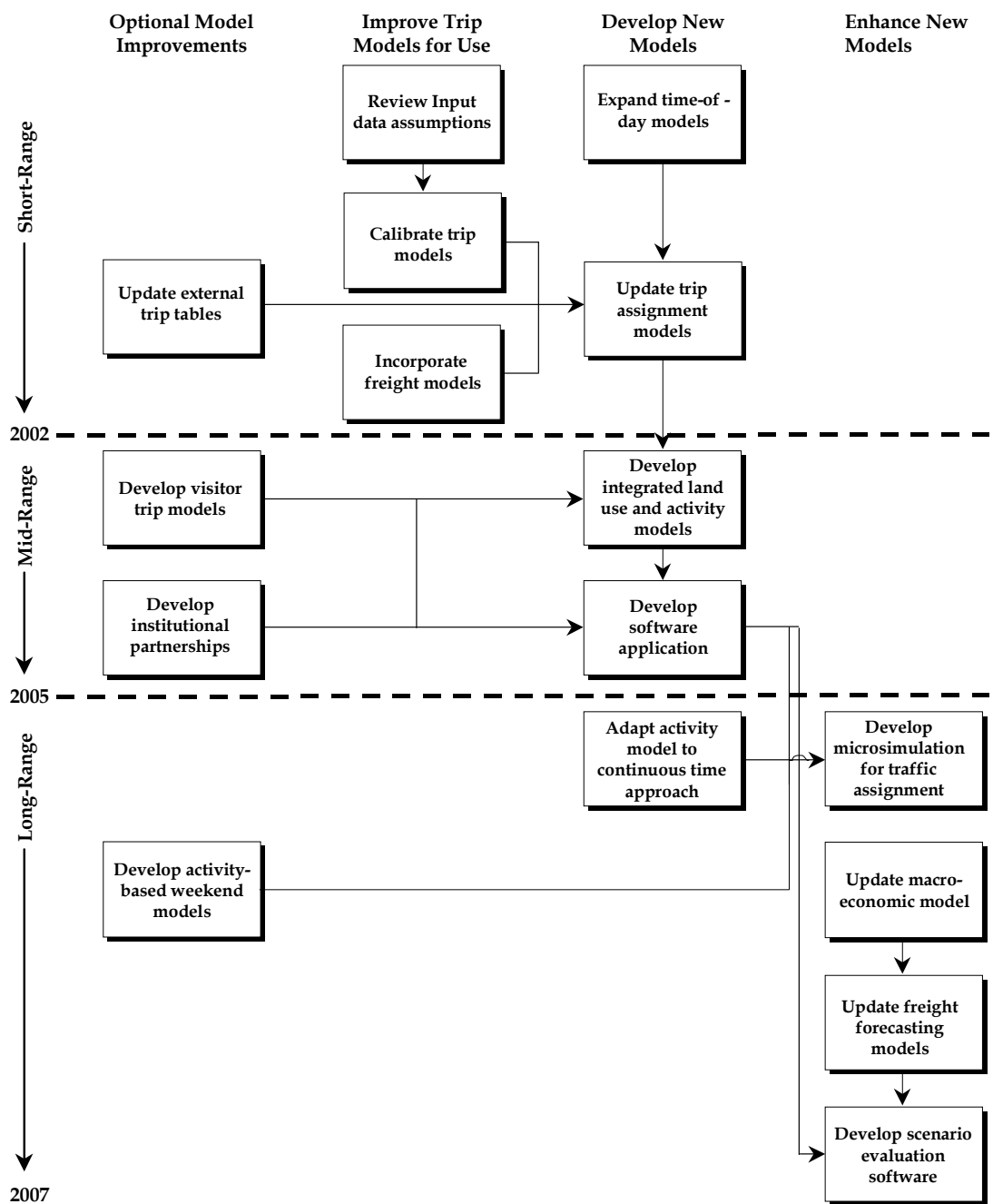
1. Optional model improvements that add value to the overall modeling system, but are not considered critical to the overall model design.
2. Model improvements to improve the 1998 trip-based models developed by the Regional Council for use in planning applications. The cost associated with calibrating trip-based models (\$100,000) applies to the 1998 models, and would be reduced to \$35,000 if the “current” trip-based models were retained for future use.
3. Model improvements needed to develop new models. There are specific model improvements that are needed to support the development of new models and other short-term improvements that are only designed to provide better models in the short term.
4. Long-term model enhancements to the new models. These longer-term recommendations are in part dependent on the state-of-the-practice for land use and activity-based models at that time, and should be reconsidered following the implementation of the mid-term recommendations.

The cost estimates are developed to support these four categories of model improvements, so that cumulative costs can be determined for each category.

### ■ 6.1 Costs

The costs for implementing the model design recommendations contained in this report are estimated here based on costs in other model applications and comparison of the scope of the proposed recommendations to these projects. The costs are necessarily general estimates at this stage, since many variables affect costs that are not known at this time, including what software platform the model will be implemented in and what partnering arrangements might be used to leverage PSRC resources. In the following estimates, we have included ranges to reflect uncertainty given these unknowns.

**Figure 6.1 Sequencing and Dependency of Model Recommendations**



## Costs by Phase

The costs presented in Table 6.1 show all model recommendations in each phase (short, mid, and long range). It is, of course, possible that specific model improvements would be implemented and others would not in each phase. All costs presented in Table 6.1 represent the high range of costs, except for subtotals and the grand total costs, where low ranges of costs are presented for indicate costs savings that are possible. These costs savings are primarily dependent on data collection (number of samples), model specifications, and other unknowns.

## Costs by Model Type

To provide further information on costs, Table 6.2 presents the same costs summarized by model type corresponding with the models presented in Figure 6.1. The costs presented in Table 6.2 represent the high range for all costs. Data costs include data collection, assessment, cleaning, development, and integration for modeling use.

## ■ 6.2 Benefits to PSRC and Member Agencies

### Addresses Current and Future Planning Needs

The vast majority of the benefits to implementing the recommendations are those associated directly with addressing the design requirements, which are stated needs that the model users have identified. These benefits are not easily quantifiable, specifically because they reach much farther than the benefits to the Puget Sound Regional Council directly and will benefit all member agencies.

The new models will allow the PSRC and its member agencies to address many more planning applications than they are able to do with the current models. These are summarized below:

- Evaluates freight mobility projects and their impacts on passenger mobility;
- Evaluates transportation pricing policies and their impacts on travel and land use choices;
- Evaluates TOD projects and their impacts on local areas;
- Evaluates CMS and TSM policies;
- Evaluates ITS projects;

**Table 6.1 Cost Estimates\* by Phase**

<b>Recommendations</b>	<b>Data Costs</b>	<b>Model Costs</b>	<b>Total Costs</b>
<i>Short-Range Implementation Recommendations (Through End of 2002)</i>			
S-1. Calibrate trip generation, distribution and mode choice models	\$25,000	\$100,000	\$125,000
S-2. Review and update input data assumptions	\$10,000	\$40,000	\$50,000
S-3. Expand the time-of-day model	\$10,000	\$10,000	\$20,000
S-4. Update external trip tables	\$70,000	\$20,000	\$90,000
S-5. Update trip assignment models		\$35,000	\$35,000
S-6. Incorporate the freight model	\$25,000	\$10,000	\$35,000
Subtotal - High Range	\$140,000	\$215,000	\$355,000
Subtotal - Low Range	\$105,000	\$161,250	\$266,250
<i>Mid-Range Implementation Recommendations (Through Mid-2005)</i>			
M-1. Develop an integrated land use and activity-based model	\$400,000	\$1,000,000	\$1,400,000
M-2. Add a visitor trip model	\$25,000	\$50,000	\$75,000
M-3. Develop integrated software architecture		\$750,000	\$750,000
M-4. Develop institutional partnerships		\$10,000	\$10,000
Subtotal - High Range	\$425,000	\$1,810,000	\$2,235,000
Subtotal - Low Range	\$318,750	\$1,357,500	\$1,676,250
<i>Long-Range Implementation Recommendations (Through Mid-2007)</i>			
L-1. Use a dynamic microsimulation traffic assignment model		\$500,000	\$500,000
L-2. Adapt the activity model to a continuous time approach		\$750,000	\$750,000
L-3. Develop weekend models	\$375,000	\$250,000	\$625,000
L-4. Update macro-economic models		\$250,000	\$250,000
L-5. Update the commodity-transport model	\$100,000	\$350,000	\$450,000
L-6. Develop an extended scenario evaluation component		\$250,000	\$250,000
Subtotal - High Range	\$475,000	\$2,350,000	\$2,825,000
Subtotal - Low Range	\$356,250	\$1,762,500	\$2,118,750
<b>Grand total - High Range</b>	<b>\$1,040,000</b>	<b>\$4,375,000</b>	<b>\$5,415,000</b>
<b>Grand Total - Low Range</b>	<b>\$780,000</b>	<b>\$3,281,250</b>	<b>\$4,061,250</b>

\* All cost estimates represent the high range of costs, except for subtotals and grand totals where low ranges are provided to indicate potential cost savings where data collection, model development, or software development specifications indicate less resources will be needed. *These low ranges are identified in italics.*

**Table 6.2 Cost Estimates\* by Model Type**

<b>Recommendations</b>	<b>Data Costs</b>	<b>Model Costs</b>	<b>Total Costs</b>
<i>Optional Model Enhancements</i>			
S-4. Update external trip tables	\$70,000	\$20,000	\$90,000
M-2. Add a visitor trip model	\$25,000	\$50,000	\$75,000
M-4. Develop institutional partnerships	\$-	\$10,000	\$10,000
L-3. Develop weekend models	\$375,000	\$250,000	\$625,000
Subtotal	\$470,000	\$330,000	\$800,000
<i>Improve Trip Models</i>			
S-1. Calibrate trip generation, distribution and mode choice models	\$25,000	\$100,000	\$125,000
S-2. Review and update input data assumptions	\$10,000	\$40,000	\$50,000
S-6. Incorporate the freight model	\$25,000	\$10,000	\$35,000
Subtotal	\$60,000	\$150,000	\$210,000
<i>Develop New Models</i>			
S-3. Expand the time-of-day model	\$10,000	\$10,000	\$20,000
S-5. Update trip assignment models	\$-	\$35,000	\$35,000
M-1. Develop an integrated land use and activity-based model	\$400,000	\$1,000,000	\$1,400,000
M-3. Develop integrated software architecture	\$-	\$750,000	\$750,000
L-2. Adapt the activity model to a continuous time approach	\$-	\$750,000	\$750,000
Subtotal	\$410,000	\$2,545,000	\$2,955,000
<i>Enhance New Models</i>			
L-1. Use a dynamic microsimulation traffic assignment model	\$-	\$500,000	\$500,000
L-4. Update macro-economic models	\$-	\$250,000	\$250,000
L-5. Update the commodity-transport model	\$100,000	\$350,000	\$450,000
L-6. Develop an extended scenario evaluation component	\$-	\$250,000	\$250,000
Subtotal	\$100,000	\$1,350,000	\$1,450,000
<b>Grand Total - High Range</b>	<b>\$1,040,000</b>	<b>\$4,375,000</b>	<b>\$5,415,000</b>
<b>Grand Total - Low Range</b>	<b>\$780,000</b>	<b>\$3,281,250</b>	<b>\$4,061,250</b>

\*All cost estimates represent the high range of costs, except for grand totals where low ranges are provided to indicate potential cost savings where data collection, model development or software development specifications indicate less resources will be needed. *These low ranges are identified in italics.*

- Evaluates traffic operations and localized impacts;
- Evaluates impacts of visitor travel;
- Evaluates impacts of weekend travel on the environment and provides better information on weekly, monthly, or annual impacts;
- Evaluates the impacts of the full range of transportation projects on land use; and
- Provides for least cost planning, risk, and uncertainty analysis and valuation of social and environmental externalities.

### **Adds New Interface Features**

The new models are also designed to be more useful and user-friendly to PSRC and its member agencies, as well as to other model users. Highlights of these new interface features are summarized below:

- Integrates land use and activity-based travel models in a single software package,
- Allows for diagnosing data quality and consistency and provides integration of data inputs for modeling with a new data integration component,
- Adds graphic visualization of results and flexible construction of performance indicators, and
- Allows distributed use of models and model results through a web-based user interface.

### **Eliminates Need for Multiple Models**

It is important to note that there are additional benefits to member agencies than those directly addressing the stated model requirements. These benefits are derived primarily from the recommendations to use disaggregate data throughout the process. These disaggregate data would allow member agencies to use the new PSRC models directly for local and subarea studies within their jurisdictions, thus saving time and effort spent in disaggregating the regional models for these purposes. The resources currently spent by the member agencies to disaggregate regional data for local use could then be spent in maintaining and updating the disaggregate data used in the new PSRC models. Consistency of data and models used by the PSRC and its members is a significant potential benefit from implementation of these recommendations.

### **Improves Accuracy and Reliability**

The advantages of developing new integrated land use and activity-based models using disaggregate data and a behavioral basis throughout cannot be over-stated. These models

are inherently more logical and are more accurate in aggregate form than their aggregate, four-step planning model counterparts, because they are based on the same decision-making choices that are present in the real world for both land use and travel decisions. Unfortunately, the benefits of improved accuracy and reliability at this point are largely anecdotal or qualitative, since there are not direct comparisons between the proposed modeling techniques and current state-of-the-practice. It may be important to note that they are not necessarily more accurate in the base year validation statistics, since models can be “tweaked” to match observed values, but would be more accurate in the forecast years. Comparisons of improved land use and activity-based models that are compared to existing techniques completed in other metropolitan areas should be reviewed when they become available to better understand these impacts.